Use of a mechanical simulator for training in applying cricoid pressure

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Summary

Using an airway management training model, we have assessed anaesthesia personnel in their use of correct cricoid force and ability to retain this skill after a short training programme. A perspex device, working on a hydraulic principle, was used to measure cricoid pressure when applied to the model. After initial assessment at two levels of cricoid force (20 and 40 N), participants undertook additional training on 3 consecutive days. Thereafter, available participants underwent reassessment at 14–21 days. Forty-nine anaesthetic assistants and anaesthetists underwent initial assessment and 18 completed the full training and reassessment. Untrained, the majority (63%) of participants applied inadequate cricoid force with a wide variation (mean 16.8 (sd 9.3) (range 4.5–43.0) at 20 N and 32.9 (13.3) (14.9–74) at 40 N). After a single training session there was a marked improvement in application of cricoid force. Two additional training sessions did not provide further improvement. After 14–21 days the ability of participants to apply correct cricoid force was retained by 72% of subjects. Those who applied inadequate cricoid force initially were more likely to do so even after training. Most subjects applied too great a cricoid force in the first 5 s of application followed by a progressive loss of force during the next 20 s. This trend improved after training. We conclude that the majority of untrained personnel apply inadequate cricoid force, placing patients at risk of aspiration of gastric contents. While a simple training programme improved application of cricoid force, retained for up to 3 weeks, there was often a substantial decrease in the force applied to the cricoid during a single application, even after training.

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Keywords


Use of cricoid pressure, as described by Sellick in 1961, is the cornerstone of rapid sequence induction to minimize the risk of pulmonary aspiration of gastric contents. The force required to occlude the oesophagus has been described “as moderate then firm pressure” 1 or “pressure which would cause pain when applied to the bridge of the nose” 2. Quantitatively, Wraight, Chamney and Howells showed that a force of 44 newtons (N) should protect 50% of patients from regurgitation 1 while Vanner and colleagues 4 showed that 40 N would increase upper oesophageal sphincter pressure (UOSP) above awake levels in 100% of subjects. However, for the awake patient 40 N is poorly tolerated 4 and may cause coughing or vomiting 1. In addition, Vanner and colleagues showed that UOSP decreased during induction of anaesthesia with thiopentone and suggested that 20 N be applied to the awake patient increasing to 40 N on loss of consciousness 5. In clinical practice, Howells and colleagues 7 demonstrated that the force applied by anaesthesia assistants varies widely, resulting in a proportion of patients remaining at risk of regurgitation because of inadequate pressure. Devices have been described 4 6 7 which allow the exact force to be applied but manual application remains the commonest method.

To reduce the proportion of patients at risk of inhalation during induction, the person applying cricoid pressure should do so correctly. This study was designed to assess, using a model, the performance of anaesthesia staff and assistants in applying cricoid pressure. Participants then underwent a training programme using the model, which was subsequently used to evaluate retention of training.

Subjects and methods

To measure the force applied to the cricoid cartilage, we designed a device which was easy to use and calibrate, and was accurate over the intended range of forces (5–60 N). The perspex device worked on the hydraulic principle (fig. 1) and allowed cricoid pressure to be applied using a three-finger technique onto the cricoid cartilage of a model (Laerdel airway management trainer, fig. 2). The device was light (50 g) and applied a minimal force (0.49 N) when placed alone on the cricoid. The yoke transmitted the force from the cricoid to the plunger which abutted the diaphragm, increasing the fluid pressure within the device in a linear fashion (r=0.98). Pressure changes were transduced electronically and displayed as a moving line on an oscilloscope (Datascope 2000 pressure transducer). The absolute pressure (in mm Hg) was displayed also and recorded. For all measurements the level of the cricoid on the model
was 95 cm above ground and the transducer was zeroed at this level before each attempt. The device was calibrated using a set of electronic scales before each assessment (1 kg = 9.81 N) (manufacturer’s specifications available on request).

Both anaesthetists and anaesthesia assistants (nursing staff) were studied. The former are expected to be able to teach the correct force to be applied while the latter regularly apply cricoid pressure as part of their nursing duties. The end-point of the study was the ability of participants, without reference to the recording device (i.e. blinded), to apply two forces, 20 N and 40 N, within the range 2.5–5 N, respectively. Each subject was assessed before training, over the 3 days of training (consecutively if possible), and 14–21 days after the third day of training.

On day 1 the initial untrained assessment was made by blocking the subject to the pressure reading on the oscilloscope and asking the subject to apply, for a period of 20 s, what they considered their “normal” cricoid force. Each was then asked to apply “half their normal” force for 20 s. These two measurements were repeated three times. The mean force of three readings obtained over the last 15 s of application was recorded. After this initial assessment, each participant then viewed the oscilloscope screen unblinded and was allowed three attempts at attaining both 20 and 40 N. Participants were again blinded to the oscilloscope screen and asked to apply “half” and then “full” cricoid pressure three times. The forces developed were again recorded. If two of the three recorded forces and the mean force were appropriate (20 ± 2.5 N and 40 ± 5 N) the participant was considered trained for that day. If the targets were not met then additional cycles of unblinded training were followed by blinded reassessment until the participant was trained. The number of training cycles each day was recorded.

On days 2 and 3 the subjects first performed a blinded assessment at 20 and 40 N to assess retention from the previous day. If training targets were not met further training cycles were conducted as above. Two to 3 weeks later (according to staff availability) subjects were reassessed to determine retention of training. All assessments were performed by the same assessor (N. A.).

The numbers of subjects applying cricoid pressure correctly were compared on each day of training with the initial assessment using McNemar’s chi-square test, with Bonferroni’s correction for repeated measures. Mean force applied at each target value was compared with the target value using z tests, and repeated measures analysis of variance was used to compare mean values on each assessment with initial performance.

Results
Forty-nine staff participated in the initial assessment: 29 were anaesthetic assistants (all female) and 20 were anaesthetists (eight female) of varying years of experience. Eighteen of the subjects (six anaesthetic assistants, 12 anaesthetists) were available to complete the full training and reassessment.

Neither sex nor rank (i.e. assistants vs anaesthetists) significantly influenced the ability to apply the correct force during any part of the study. While not quantitatively assessed, we observed that most subjects applied a much greater force at the beginning of application than at the end of the 20 s period and there was often an “overshoot” of applied force in the initial 5 s. This decline in applied force with time was still present after training but was less marked. Figure 3 shows examples of forces applied.

At the initial assessment, mean applied cricoid forces of 16.8 (sd 9.3) (range 4.5–43.0) N and 32.9 (13.3) (14.9–74) N were significantly (P < 0.01 and < 0.001, respectively) below the targets of 20 N and 40 N, respectively. The majority of subjects (67% at 20 N and 61% at 40 N) were unable to achieve the lowest force considered acceptable (17.5 N and 35 N, respectively). Only five subjects (10%) at 20 N and nine subjects (18%) at 40 N were able to apply pressures within the correct ranges.

Figure 4 shows the applied cricoid force at the targets of 20 and 40 N at the initial assessment and subsequent assessments after training for the 18 subjects who completed the training in full. At the initial assessment the only difference between the results of the 18 subjects who completed the study and the total of 49 subjects was that the difference between the mean force applied and 20 N was not statistically significant. Following training after the initial assessment on day 1 and subsequent training on days 2 and 3, there was a significant increase in the mean cricoid force applied at both the 20 and 40 N targets compared with the initial assessment. At the 40 N target, the mean values after training were within an acceptable range of the target value (35–45 N). At the 20 N target, however, mean values were greater than the upper limit of the acceptable range (17.5–22.5 N). Mean values at the 40 N target were significantly different from 40 N at the initial assessment (z = 3.02, P < 0.01) and after training on day 1 (z = 3.01, P < 0.01) but not on days 2 (z = 2.16, 0.05 > P > 0.01) or 3 (z = 1.96, 0.05 > P > 0.01). At the 20 N target, mean values did not differ significantly from...
the target at the initial assessment \( z = 1.61, \text{ns} \) or on day 1 \( z = 2.01, 0.05 > P > 0.01 \) but were significantly different on days 2 \( z = 3.11, P < 0.01 \) and 3 \( z = 4.43, P < 0.01 \).

There was a statistically significant \( P < 0.0125 \) reduction in the variability of applied pressures (coefficient of variation) at the 40 N target on days 1, 2 and 3 compared with the initial assessment. Coefficient of variations were 0.38 at the initial assessment, 0.13 on day 1, 0.17 on day 2 and 0.12 on day 3. At the 20 N target, however, a similar reduction in the coefficient of variation was seen only on days 1 and 3 (coefficient of variation for the 20 N target: initial 0.52; day 1, 0.27; day 2, 0.39; day 3, 0.25).

At the final assessment, 2–3 weeks after the last training cycle, the mean forces applied were within the acceptable range for both the 20 N and 40 N targets. At the 40 N target the mean force applied (38.9 \( (5.9) \) N) on the final assessment remained significantly higher than that obtained at the initial assessment (31.4 \( (12.0) \) N). Seven of the 18 subjects

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**Figure 2** The cricoid measuring device was applied to an airway training model using a three-finger technique.

**Figure 3** Three typical tracings of inadequate application of cricoid force. A and B show the marked initial overshoot and later decline of cricoid force while C shows the force to be low throughout, even though the subject had undergone training.

**Figure 4** Cricoid force (mean, range and interquartile range) applied at the initial and subsequent assessments at the 20 N (bottom curve) and 40 N (top curve) targets. *\( P < 0.05 \) compared with initial assessment; †\( P < 0.05 \) compared with target value.
applied inappropriate cricoid force both at the initial and final assessments. At the final assessment two applied too much force, four applied 34 N and one 32 N. At the 20 N target there was no statistically significant difference between the mean force applied on the final day (20.3 (7.0) N) compared with the initial assessment (16.7 (8.7) N). However, at both 20 and 40 N targets the mean applied force was no longer significantly different from the target force (z = 0.16 at 20 N, and 0.81 at 40 N, ns).

At the initial assessment only one subject at the 20 N target and three subjects at the 40 N target achieved cricoid forces within the acceptable range (table 1). Performance improved on subsequent days but a statistically significant (P<0.0125) improvement in the number of subjects achieving acceptable forces was only seen in the 40 N group on the final assessment. There was a trend towards an increase in the number of subjects applying too great a force during the training period but the sample was of insufficient size to obtain statistical significance.

One subject who applied a force within the acceptable range for the 20 N target at the initial assessment was outside the range at the final assessment. Between 1 and 3 training cycles were required after assessment on each day to achieve an applied force within the acceptable range at both the 20 N and 40 N targets. No statistically significant reduction in the number of training cycles required was observed during the training period.

Discussion

For cricoid pressure to prevent pulmonary aspiration of gastric contents, the UOSP generated must be greater than the pressure within the lower oesophagus. Wraight, Chamney and Howells3 calculated that the maximum possible passive oesophageal pressure generated in a gravid patient given suxamethonium was 7.84 kPa, and showed further that this UOSP was generated in 50% of subjects given 44 N of cricoid force. Taking into account the force generated by a tracheal tube and accepting the resting awake UOSP of 38 mm Hg as an adequate target, Vanner and colleagues4 showed that after 14–21 days the ability to apply correct cricoid force was retained by most subjects. However, 28% of subjects still applied a force less than 35 N. As none of these subjects applied grossly inadequate force (< 30 N) we consider this to be acceptable. This study was not designed to answer the question of how often training should be repeated, but work by Berden and colleagues9 suggests that resuscitation skills in nurses are maintained for between 3 and 6 months and it would seem reasonable therefore that training should be repeated at least every 6 months. The evidence from this study is that retention of training deteriorates more rapidly.

The decrease in the applied force over the period of 20 s seen in our study has been observed previously5. The results give rise to concern about the

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*P < 0.0125; †0.05 > P > 0.0125 compared with initial percentage of participants applying inadequate cricoid pressure.
quality of cricoid force applied over a protracted period during, for example, a difficult intubation.

The inadequate force applied, the wide individual variability seen particularly at 20 N, and the decline in applied force with time in untrained personnel strengthen the argument for the need for a mechanical device to allow correct cricoid force to be applied consistently. However, a questionnaire conducted by Howells and colleagues suggested that only 33% of anaesthetists in the UK and USA believed a mechanical device would be useful and only 46% believed a training device necessary. Many devices have been described and demonstrated to be effective in training subjects to apply correct cricoid force but none have been adopted into general practice possibly because they have been associated with laryngeal distortion and difficult intubation. Our device being smaller and lighter may allow more accurate placement, reducing laryngeal distortion, although this has yet to be assessed.

We conclude that training improves performance but retention of the skill of applying appropriate cricoid pressure for any length of time cannot be guaranteed. Indeed some staff may be untrainable. Our results imply that staff applying cricoid pressure should undergo a frequent training programme, the interval of which remains to be determined but may need to be monthly. Introducing such training programmes into clinical practice may well be logistically prohibitive. Alternatively such programmes may form part of courses in airway management. In addition, the value of introduction of such training programmes in the context of improved morbidity or mortality from such a rare event as acid aspiration is unlikely to be significant. Nevertheless if cricoid pressure is to be applied then only appropriate techniques can be acceptable. While the idea of applying moderate cricoid pressure (20 N) before induction is laudable, the difficulty experienced by our subjects in attaining this pressure suggest that this goal may be difficult to achieve.

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References

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